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NOTIFICATION CONCERNING
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(PCT Administrative Instructions, Section 411)

From the INTERNATIONAL BUREAU

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Applicant SHOWA DENKO K.K. et al	

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<u>Priority date</u>	<u>Priority application No.</u>	<u>Country or regional Office or PCT receiving Office</u>	<u>Date of receipt of priority document</u>
18 July 2000 (18.07.00)	2000-217610	JP	17 Augu 2001 (17.08.01)
07 Sept 2000 (07.09.00)	60/230,811	US	27 July 2001 (27.07.01)
27 Dece 2000 (27.12.00)	2000-397269	JP	17 Augu 2001 (17.08.01)
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DECLARATION

I, Atsuko Ikeda, residing at 26-2-906, Ojima 3-chome, Koto-ku, Tokyo, Japan, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof. I further certify that to the best of my knowledge and belief the attached English translation is a true and correct translation made by me of U.S. Provisional Patent Application No. 60/261,265 filed on January 16, 2001.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 4th day of June, 2001



Atsuko Ikeda

[NAME OF DOCUMENT] Specification

[TITLE OF THE INVENTION]

Cleaning Gas for Semiconductor Production Equipment,
and Cleaning Method Using the Same

[SCOPE OF CLAIM FOR PATENT]

[Claim 1] A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, said cleaning gas comprising SF_6 , NF_3 and an inert gas.

[Claim 2] The cleaning gas for semiconductor production equipment as claimed in claim 1, wherein the inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and N_2 .

[Claim 3] The cleaning gas for semiconductor production equipment as claimed in claim 2, wherein the inert gas is at least one gas selected from the group consisting of He, Ar and N_2 .

[Claim 4] The cleaning gas for semiconductor production equipment as claimed in any one of claims 1 to 3, wherein the mixing ratio of SF_6 , NF_3 and inert gas is such that NF_3 is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms of the volume ratio assuming that SF_6 is 1.

[Claim 5] The cleaning gas for semiconductor production equipment as claimed in claim 4, wherein the mixing ratio of SF_6 , NF_3 and inert gas is such that NF_3 is

from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that SF_6 is 1.

[Claim 6] The cleaning gas for semiconductor production equipment as claimed in any one of claims 1 to 5, which contains at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.

[Claim 7] The cleaning gas for semiconductor production equipment as claimed in claim 6, wherein said perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and said perfluoroether and hydrofluoroether each has from 2 to 4 carbon atoms.

[Claim 8] A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of claims 1 to 7.

[Claim 9] The method for cleaning semiconductor production equipment as claimed in claim 8, wherein the cleaning gas described in any one of claims 1 to 7 is excited to produce plasma and the cleaning of deposits in the semiconductor production equipment is performed in said plasma.

[Claim 10] The method for cleaning semiconductor production equipment as claimed in claim 9, wherein the exciting source for the plasma is a microwave.

[Claim 11] The method for cleaning semiconductor

production equipment as claimed in any one of claims 8 to 10, wherein the cleaning gas described in any one of claims 1 to 7 is used at a temperature range of 50 to 500°C.

[Claim 12] The method for cleaning semiconductor production equipment as claimed in claim 8, wherein the cleaning gas described in any one of claims 1 to 7 is used at a temperature range of 200 to 500°C in a plasmaless system.

[Claim 13] A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas comprising SF_6 , NF_3 , and an inert gas, and a decomposition step of decomposing a fluorocompound-containing gas discharged from said cleaning step.

[Claim 14] The method for producing a semiconductor device as claimed in claim 13, wherein said fluorocompound is at least one compound selected from the group consisting of HF , SiF_4 , SF_6 , SF_4 , SOF_2 , SO_2F_2 , NF_3 , and WF_6 .

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field to Which the Invention Belongs]

The present invention relates a cleaning gas and a cleaning method for cleaning unnecessary deposits in film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid crystal device, which are accumulated at the film formation or etching of silicon,

silicon nitride, silicon oxide, tungsten and the like, and also relates to a method for producing a semiconductor device.

[0002]

[Background Art]

In the film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid crystal device, the deposits accumulated at the film-formation or etching of silicon, silicon nitride, silicon oxide, tungsten and the like cause generation of particles and hinder the production of good film, therefore, these deposits must be cleaned on occasion.

[0003]

Heretofore, the deposits in semiconductor production equipment are removed by a method of etching the deposits using a plasma excited from a fluorine-type etching gas such as NF_3 , CF_4 and C_2F_6 . However, the method of using NF_3 has a problem in that the NF_3 is expensive, and the method of using perfluorocarbon such as CF_4 and C_2F_6 has a problem in that the etching rate is low and the cleaning efficiency is low.

[0004]

JP-A-8-60368 (the term "JP-A" as used herein means an "unexamined published Japanese patent application") describes a method of using a cleaning gas where at least

one gas of F_2 , ClF_3 , BrF_3 and BrF_5 is mixed in an amount of 1 to 50 vol% with CF_4 or C_2F_6 . Also, JP-A-10-72672 describes a method of using F_2 diluted with an inert carrier gas as the cleaning gas. However, these methods have a problem in that the etching rate is lower and the cleaning efficiency is lower than the method of using NF_3 as a cleaning gas.

[0005]

JP-A-3-146681 describes a mixed gas composition for cleaning, where at least one gas of F_2 , Cl_2 and a halogen fluoride is mixed in an amount of 0.05 to 20 vol% with NF_3 to improve the etching rate. Also, a plasmaless cleaning method using a halogen fluoride such as ClF_3 as the cleaning gas is known. However, the halogen fluoride is very expensive and moreover, extremely highly reactive, therefore, despite the excellent cleaning efficiency, there is a problem in that the greatest possible care is necessary for the handling. Furthermore, the halogen fluoride may damage the equipment material inside the semiconductor production equipment and therefore, its use is disadvantageously limited only to some devices such as CVD device.

[0006]

That is, conventionally known cleaning gases have the following problems:

(1) the gases having high cleaning efficiency are

expensive; and

(2) the gases cannot be used except for some devices.

Inexpensive cleaning gases have a problem in that the etching rate is low and the cleaning efficiency is low.

[0007]

[Problems to be Solved by the Invention]

The present invention has been made under these circumstances. Accordingly, the object of the present invention is to provide a cleaning gas and a cleaning method, which ensure high etching rate, high cleaning efficiency and excellent cost performance. Another object of the present invention is to provide a method for producing a semiconductor device.

[0008]

[Means to Solve the Problems]

As a result of extensive investigations to solve the above-described problems, the present inventors have found that a cleaning gas obtained by mixing SF_6 , NF_3 , and an inert gas at a specific ratio is remarkably improved in the etching rate and elevated in the cleaning efficiency. The present invention has been accomplished based on this finding. The present invention provides a cleaning gas and a cleaning method for cleaning semiconductor production equipment, and a method for producing a semiconductor device, described in (1) to (14) below.

[0009]

(1) A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, the cleaning gas comprising SF_6 , NF_3 , and an inert gas.

(2) The cleaning gas for semiconductor production equipment as described in (1) above, wherein the inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and N_2 .

(3) The cleaning gas for semiconductor production equipment as described in (2) above, wherein the inert gas is at least one gas selected from the group consisting of He, Ar and N_2 .

(4) The cleaning gas for semiconductor production equipment as described in any one of (1) to (3) above, wherein the mixing ratio of SF_6 , NF_3 , and inert gas is such that NF_3 is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms of the volume ratio assuming that SF_6 is 1.

(5) The cleaning gas for semiconductor production equipment as described in (4) above, wherein the mixing ratio of SF_6 , NF_3 , and inert gas is such that NF_3 is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that SF_6 is 1.

[0010]

(6) The cleaning gas for semiconductor production

equipment as described in any one of (1) to (5) above, which contains at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.

(7) The cleaning gas for semiconductor production equipment as described in (6) above, wherein the perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and hydrofluoroether each has from 2 to 4 carbon atoms.

(8) A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of (1) to (7) above.

(9) The method for cleaning semiconductor production equipment as described in (8) above, wherein the cleaning gas described in any one of (1) to (7) above is excited to produce plasma and the cleaning of deposits in the semiconductor production equipment is performed in the plasma.

(10) The method for cleaning semiconductor production equipment as described in (9) above, wherein the exciting source for the plasma is a microwave.

[0011]

(11) The method for cleaning semiconductor production equipment as described in any one of (8) to (10) above, wherein the cleaning gas described in any one of (1) to (7)

above is used at a temperature range of 50 to 500°C.

(12) The method for cleaning semiconductor production equipment as described in (8) above, wherein the cleaning gas described in any one of (1) to (7) above is used at a temperature range of 200 to 500°C in a plasmaless system.

(13) A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas comprising SF_6 , NF_3 , and an inert gas, and a decomposition step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

(14) The method for producing a semiconductor device as described in (13) above, wherein the fluorocompound is at least one compound selected from the group consisting of HF , SiF_4 , SF_6 , SF_4 , SOF_2 , SO_2F_2 , NF_3 , and WF_6 .

[0012]

That is, the present invention provides "a cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, the cleaning gas comprising SF_6 , NF_3 , and an inert gas", "a method for cleaning semiconductor production equipment, comprising use of the above-described cleaning gas" and "a method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas comprising SF_6 , NF_3 , and an inert gas, and a decomposition step of decomposing a fluorocompound-containing gas

discharged from the cleaning step".

[0013]

[Mode for Carrying Out the Invention]

The present invention is described in detail below.

The cleaning gas for semiconductor production equipment of the present invention comprises SF_6 , NF_3 , and an inert gas.

The inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and N_2 . Among these, the inert gas is preferably at least one gas selected from the group consisting of He, Ar and N_2 , because the cleaning gas can exhibit high etching rate and excellent cost performance.

[0014]

The mixing ratio of the cleaning gas of the present invention is not particularly limited, however, the mixing gas is usually such that NF_3 is from 0.01 to 5, preferably from 0.1 to 1.5, and the inert gas is from 0.01 to 500, preferably from 0.1 to 300, more preferably from 0.1 to 30, in terms of the volume ratio assuming that SF_6 is 1. The SF_6 and NF_3 gases are active as a gas for manufacturing a semiconductor or a liquid crystal and preferably used in a large amount, however, if these gases are activated moreover in plasma on use, the equipment material in the plasma atmosphere may be damaged. On the other hand, if the

amount added is too small, the effect is disadvantageously low. These gases may be mixed inside the semiconductor production equipment or in the pipeline leading to the semiconductor production equipment, or the gases may be previously mixed in a gas cylinder.

[0015]

In the cleaning gas for semiconductor production equipment of the present invention, an NF_3 gas capable of dissociating particularly at a low energy level and producing an active species is mixed and therefore, the effect brought out surpasses the effect by conventionally used cleaning gas or etching gas, such as CF_4 or C_2F_6 . The synergistic effect by the mixing is presumed to occur because the active species produced at a low energy level soritically acts on undissociated molecule and accelerates the dissociation.

[0016]

The cleaning gas of the present invention may contain at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether, in the mixed gas comprising SF_6 , NF_3 , and an inert gas. The perfluorocarbon and hydrofluorocarbon each is a compound having from 1 to 4 carbon atoms. Examples of the saturated perfluorocarbon compound include CF_4 , C_2F_6 and C_3F_8 , examples of the unsaturated

perfluorocarbon compound include C_2F_4 , C_3F_6 and C_4F_6 , and examples of the hydrofluorocarbon include CHF_3 and $C_2H_2F_4$. The perfluoroether and hydrofluoroether each is a compound having from 2 to 4 carbon atoms. Examples of the perfluoroether include CF_3OCF_3 and $CF_3OCF_2CF_3$, and examples of the hydrofluoroether include CHF_2OCHF_2 and $CHF_2OCH_2CF_3$. The mixing ratio of the gas such as perfluorocarbon is from 0.01 to 1, preferably from 0.01 to 0.5, more preferably from 0.01 to 0.2, in terms of the volume ratio assuming that the mixed gas comprising SF_6 , NF_3 and an inert gas is 1.

[0017]

In the case of cleaning semiconductor production equipment using the cleaning gas of the present invention, the gas may be used under the plasma condition or under the plasmaless condition.

When the gas is used under the plasma condition, the excitation source is not particularly limited as long as plasma is excited from the cleaning gas of the present invention, but a microwave excitation source is preferred because good cleaning efficiency can be attained. Also, the temperature and the pressure when the cleaning gas of the present invention is used are not particularly limited as long as plasma can be produced, but the temperature range is preferably from 50 to 500°C and the pressure range is preferably from 1 to 133 Pa.

[0018]

In the case of plasmaless condition, the cleaning gas is introduced into a chamber, the inner pressure of the chamber is preferably set to 1 to 67 Pa and at least a part of or either one of the inside of chamber and the cleaning gas is heated at 200 to 500°C to generate free fluorine having reactivity from the cleaning gas. Then, deposits are etched and removed from the chamber and from other regions where deposits are accumulated, and thereby the semiconductor production equipment can be cleaned.

[0019]

Fig. 1 is a view showing one example of the etching equipment using the cleaning gas of the present invention. The cleaning gas is introduced into a chamber 1 set at a constant temperature from a cleaning gas inlet 6 and at this time, the gas is excited by a microwave plasma excitation source 4 and produces plasma. The gas obtained after the etching of a silicon wafer 2 is discharged by a dry pump 5 and rendered harmless using a decomposing agent according to the gases contained therein. Furthermore, the deposits accumulated after the etching are efficiently removed by repeating the same operation as the etching, and thereby the chamber can be efficiently cleaned.

[0020]

The method for producing a semiconductor device of the

present invention is described below.

As described above, according to the present invention, the cleaning of semiconductor production equipment can be efficiently performed. However, the gas discharged from the cleaning step using the cleaning gas of the present invention contains fluorocompounds such as HF, SiF₄, SF₄, SOF₂, SO₂F₂ and WF₆, in addition to SF₆ and NF₃ used as the cleaning gas. If these compounds including SF₆ and NF₃ are discharged intact into atmosphere, they greatly affect the global warming or generate an acid gas by decomposition, therefore, each compound must be completely rendered harmless. In the method for producing a semiconductor device, the present invention provides a production method of a semiconductor device, comprising a cleaning step of cleaning semiconductor production equipment and a step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

[0021]

The step of cleaning semiconductor production equipment can be efficiently performed by using the method described above. The method for use in the step of decomposing the fluorocompound-containing gas discharged from the cleaning step is not particularly limited and the decomposing agent can be appropriately selected according to the kind of the compound contained in the exhaust gas.

However, hydrogen fluoride, SO_x and the like are preferably fixed as a fluoride or a sulfate of metal, and carbon is preferably discharged after completely decomposing it into carbon dioxide.

[0022]

[Examples]

The present invention is described in greater detail below by referring to the Examples and Comparative Examples, however, the present invention is not limited to these Examples.

(Examples 1 to 3)

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 1 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a silicone wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicone wafer after the etching and the results are shown in Table 1.

[0023]

[Table 1]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF ₆	NF ₃	He	
1	1	1	200	200
2	1	0.5	170	180
3	1	1.5	250	190

[0024]

(Comparative Examples 1 to 5)

The etching rate of each cleaning gas was determined in the same manner as in Examples 1 to 3 except that the cleaning gas was changed to a gas having the composition shown in Table 2.

[0025]

[Table 2]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)		Etching Rate (nm/min)
	Gas Used	Mixing Ratio	
1	NF ₃ /He	1/100	190
2	SF ₆ /He	1/100	70
3	F ₂ /He	1/100	170
4	CF ₄ /He	1/100	17
5	C ₂ F ₆ /He	1/100	6

Among the cleaning gases mixed with He shown in Table 2, the etching rate was highest in the case of using NF₃.

[0026]

(Comparative Examples 6 to 8)

The etching rate was determined in the same manner as in Examples 1 to 3 except that the cleaning gases were changed to the gases each having the composition shown in Table 3.

[0027]

[Table 3]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	NF ₃	F ₂	He	
6	1	1	200	175
7	1	0.5	170	170
8	1	1.5	250	170

All of the etching rate of the mixed gases shown in Comparative Examples 6 to 8 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 3.

[0028]

(Comparative Examples 9 to 11)

The etching rate was determined in the same manner as in Examples 1 to 3 except that the cleaning gases were changed to the gases each having the composition shown in Table 4.

[0029]

[Table 4]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	CF ₄	F ₂	He	
9	1	1	200	140
10	1	0.5	170	120
11	1	1.5	250	155

All of the etching rate of the mixed gases shown in Comparative Examples 9 to 11 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 3.

[0030]

(Comparative Examples 12 to 14)

The etching rate was determined in the same manner as in Examples 1 to 3 except that the cleaning gases were changed to the gases each having the composition shown in Table 5.

[0031]

[Table 5]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	C ₂ F ₆	F ₂	He	
12	1	1	200	50
13	1	0.5	170	30
14	1	1.5	250	100

All of the etching rate of the mixed gases shown in

Comparative Examples 12 to 14 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 3.

[0032]

(Comparative Example 15)

The etching rate was determined in the same manner as in Examples 1 to 3 except that the cleaning gas was changed to a gas having the composition shown in Table 6.

[0033]

[Table 6]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)		Etching Rate (nm/min)
	Gas Used	Mixing Ratio	
15	NF ₃ /He	1/10	1,900

It is seen that when the concentration of NF₃ was increased to ten times that of Comparative Example 1, the etching rate also became ten times higher.

[0034]

(Example 4)

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 1 to 3 except that the cleaning gas was changed to a gas having the composition shown in Table 7.

[0035]

[Table 7]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF ₆	NF ₃	He	
4	1	1	20	2,200

The etching rate of the cleaning gas of the present invention shown in Example 4 was more excellent than the rate of NF₃ shown in Comparative Example 15.

[0036]

(Example 5)

In place of a silicone wafer, a quartz piece having accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning. The cleaning gas used in Example 1 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus adjusted to an inner pressure of 300 Pa, and the quartz piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

[0037]

[Effects of the Invention]

The cleaning gas for semiconductor production equipment of the present invention is high in the etching rate, therefore, ensures efficient cleaning and excellent cost performance. According to the method for cleaning

semiconductor production equipment of the present invention, unnecessary deposits in the film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid crystal element accumulated at the film-formation or etching of silicon, silicon nitride, silicon oxide, tungsten or the like can be efficiently cleaned. Furthermore, by using the method comprising a cleaning step of using the cleaning gas of the present invention and a step of decomposing and thereby rendering harmless the fluorocompound-containing exhaust gas discharged from the cleaning step, a semiconductor device can be efficiently produced.

[BRIEF DESCRIPTION OF DRAWING]

[Fig. 1]

Fig. 1 is a schematic view of etching equipment using the cleaning gas of the present invention.

[Description of Reference Numerals]

- 1 chamber
- 2 silicone wafer
- 3 sample stage
- 4 microwave plasma excitation source
- 5 dry pump
- 6 cleaning gas inlet

[NAME OF THE DOCUMENT] Abstract

[SUMMARY]

[PROBLEM TO BE SOLVED]

To provide a cleaning gas favored with high etching rate, high cleaning efficiency and excellent cost performance, a cleaning method, and a method for producing a semiconductor device.

[MEANS TO SOLVE THE PROBLEM]

A cleaning gas and a cleaning method for cleaning semiconductor production equipment using a cleaning gas obtained by mixing SF_6 , NF_3 , and an inert gas at a specific ratio.

[SELECTED DRAWING] None.

DESCRIPTION

Cleaning Gas for Semiconductor Production Equipment

5 CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on the provisions of 35 U.S.C. Article 111(a) with claiming the benefit of filing dates of U.S. provisional application Serial No. 60/230,811 filed on September 7, 2000 and U.S. 10 provisional application Serial No.60/261,265 filed on December 27, 2000 under the provisions of 35 U.S.C. 111(b), pursuant to 35 U.S.C. Article 119(e) (1).

TECHNICAL FIELD

15 The present invention relates a cleaning gas for semiconductor production equipment. Specifically, the present invention relates to a cleaning gas for removing unnecessary deposits in film-forming equipment or etching equipment for the production of a semiconductor or a TFT 20 liquid crystal device, which are accumulated at the film formation or etching of silicon, silicon nitride, silicon oxide, tungsten and the like, to a cleaning method using the cleaning gas, and also to a method for producing a semiconductor device including a cleaning step using the 25 cleaning gas.

BACKGROUND ART

In the film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid 30 crystal device, the deposits accumulated at the film-formation or etching of silicon, silicon nitride, silicon oxide, tungsten and the like cause generation of particles and hinder the production of good film,

therefore, these deposits must be removed on occasion.

Heretofore, the deposits in semiconductor production equipment are removed by a method of etching the deposits using a plasma excited from a fluorine-type etching gas such as NF_3 , CF_4 and C_2F_6 . However, the method of using NF_3 has a problem in that the NF_3 is expensive, and the method of using perfluorocarbon such as CF_4 and C_2F_6 has a problem in that the etching rate is low and the cleaning efficiency is low.

JP-A-8-60368 (the term "JP-A" as used herein means an "unexamined published Japanese patent application") describes a method of using a cleaning gas where at least one gas of F_2 , ClF_3 , BrF_3 and BrF_5 is mixed in an amount of 1 to 50 vol% with CF_4 or C_2F_6 . Also, JP-A-10-72672 describes a method of using F_2 diluted with an inert carrier gas as the cleaning gas. However, these methods have a problem in that the etching rate is lower and the cleaning efficiency is lower than the method of using NF_3 as a cleaning gas.

JP-A-3-146681 describes a mixed gas composition for cleaning, where at least one gas of F_2 , Cl_2 and a halogen fluoride is mixed in an amount of 0.05 to 20 vol% with NF_3 to improve the etching rate. Also, a plasmaless cleaning method using a halogen fluoride such as ClF_3 as the cleaning gas is known. However, the halogen fluoride is very expensive and moreover, extremely highly reactive, therefore, despite the excellent cleaning efficiency, there is a problem in that the greatest possible care is necessary for the handling. Furthermore, the halogen fluoride may damage the equipment material inside the semiconductor production equipment and therefore, its use is disadvantageously limited only to some devices such as CVD device.

That is, conventionally known cleaning gases have the following problems:

(1) the gases having high cleaning efficiency are expensive; and

5 (2) the gases cannot be used except for some devices.

Inexpensive cleaning gases have a problem in that both the etching rate and the cleaning efficiency are low.

The present invention has been made under these
10 circumstances. Accordingly, one of the objects of the present invention is to provide a cleaning gas and a cleaning method, which ensure high etching rate, high cleaning efficiency and excellent cost performance. One
15 of the objects of the present invention is to provide a method for producing a semiconductor device.

DISCLOSURE OF THE INVENTION

As a result of extensive investigations to solve the
20 above-described problems, the present inventors have found that a cleaning gas obtained by mixing SF_6 and one or both of F_2 and NF_3 with an inert gas at a specific ratio is remarkably improved in the etching rate and elevated in the cleaning efficiency. Moreover, the
25 present inventors have found that the cleaning efficiency is further improved by using the cleaning gas with an oxygen-containing gas contained therein in a specific ratio.

The present invention relates to a cleaning gas for
30 cleaning semiconductor production equipment as described in (1) to (22) below, to a cleaning method as described in (23) to (32) below, and to a method for producing a semiconductor device, described in (33) and (36) below.

(1) A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in the equipment, comprising an inert gas and at least two gases selected from the group consisting of SF_6 , F_2 , and NF_3 excluding the combination of F_2 and NF_3 alone.

(2) The cleaning gas for semiconductor production equipment as described in (1) above, comprising SF_6 , F_2 , and an inert gas.

(3) The cleaning gas for semiconductor production equipment as described in (1) above, comprising SF_6 , NF_3 , and an inert gas.

(4) The cleaning gas for semiconductor production equipment as described in (1) above, comprising SF_6 , F_2 , NF_3 , and an inert gas.

(5) The cleaning gas for semiconductor production equipment as described in any one of (1) to (4) above, wherein the inert gas is at least one selected from the group consisting of He, Ne, Ar, Xe, Kr and N_2 .

(6) The cleaning gas for semiconductor production equipment as described in (5) above, wherein the inert gas is at least one selected from the group consisting of He, Ar, and N_2 .

(7) The cleaning gas for semiconductor production equipment as described in (1) above, wherein F_2 and/or NF_3 is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms of the volume ratio assuming that SF_6 is 1.

(8) The cleaning gas for semiconductor production equipment as described in (7) above, wherein F_2 and/or NF_3 is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that SF_6 is 1.

(9) The cleaning gas for semiconductor production equipment as described in (1) above, which contains at least one gas selected from the group consisting of

perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.

(10) The cleaning gas for semiconductor production equipment as described in (9) above, wherein the
5 perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and hydrofluoroether each has from 2 to 4 carbon atoms.

(11) A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits
10 in the equipment, comprising an oxygen-containing gas, an inert gas and at least two gases selected from the group consisting of SF_6 , F_2 , and NF_3 excluding the combination of F_2 and NF_3 alone.

(12) The cleaning gas for semiconductor production equipment as described in (11) above, comprising an inert
15 gas, an oxygen-containing gas, SF_6 , and F_2 .

(13) The cleaning gas for semiconductor production equipment as described in (11) above, comprising an oxygen-containing gas, an inert gas, SF_6 , and NF_3 .

20 (14) The cleaning gas for semiconductor production equipment as described in (11) above, comprising an oxygen-containing gas, an inert gas, SF_6 , F_2 and NF_3 .

(15) The cleaning gas for semiconductor production equipment as described in any one of (11) to (14) above,
25 wherein the oxygen-containing gas is at least one selected from the group consisting of O_2 , O_3 , N_2O , NO , NO_2 , CO and CO_2 .

(16) The cleaning gas for semiconductor production equipment as described in (15) above, wherein the oxygen-
30 containing gas is O_2 and/or N_2O .

(17) The cleaning gas for semiconductor production equipment as described in any one of (11) to (14) above, wherein the inert gas is at least one selected from the

group consisting of He, Ne, Ar, Xe, Kr and N₂.

(18) The cleaning gas for semiconductor production equipment as described in (17) above, wherein the inert gas is at least one selected from the group consisting of
5 He, Ar, and N₂.

(19) The cleaning gas for semiconductor production equipment as described in (11) above, wherein F₂ and/or NF₃ is from 0.01 to 5, the oxygen-containing gas is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms
10 of the volume ratio assuming that SF₆ is 1.

(20) The cleaning gas for semiconductor production equipment as described in (19) above, wherein F₂ and/or NF₃ is from 0.1 to 1.5, the oxygen-containing gas is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms
15 of the volume ratio assuming that SF₆ is 1.

(21) The cleaning gas for semiconductor production equipment as described in (11) above, which contains at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and
20 hydrofluoroether.

(22) The cleaning gas for semiconductor production equipment as described in (21) above, wherein the perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and
25 hydrofluoroether each has from 2 to 4 carbon atoms.

(23) A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of (1) to (10) above.

(24) The method for cleaning semiconductor
30 production equipment as described in (23) above, wherein the cleaning gas described in any one of (1) to (10) above is excited to produce plasma and the deposits in the semiconductor production equipment are removed in the

plasma.

(25) The method for cleaning semiconductor production equipment as described in (24) above, wherein the excitation source for the plasma is a microwave.

5 (26) The method for cleaning semiconductor production equipment as described in any one of (23) to (25) above, wherein the cleaning gas described in any one of (1) to (10) above is used at a temperature range of 50 to 500°C.

10 (27) The method for cleaning semiconductor production equipment as described in (23) above, wherein the cleaning gas described in any one of (1) to (10) above is used at a temperature range of 200 to 500°C in a plasmaless system.

15 (28) A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of (11) to (22) above.

(29) The method for cleaning semiconductor production equipment as described in (28) above, wherein
20 the cleaning gas described in any one of (11) to (22) above is excited to produce plasma and the deposits in the semiconductor production equipment are removed in the plasma.

(30) The method for cleaning semiconductor
25 production equipment as described in (29) above, wherein the excitation source for the plasma is a microwave

(31) The method for cleaning semiconductor production equipment as described in any one of (28) to (30) above, wherein the cleaning gas described in any one
30 of (11) to (22) above is used at a temperature range of 50 to 500°C.

(32) The method for cleaning semiconductor

production equipment as described in (28) above, wherein the cleaning gas described in any one of (11) to (22) above is used at a temperature range of 200 to 500°C in a plasmaless system.

5 (33) A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas containing an inert gas and at least two gases selected from the group consisting of SF₆, F₂ and NF₃ excluding the combination of F₂ and NF₃ alone, and a decomposition step
10 of decomposing a fluorocompound-containing gas discharged from the cleaning step.

 (34) The method for producing a semiconductor device as described in (33) above, wherein the fluorocompound is at least one compound selected from the group consisting
15 of HF, SiF₄, SF₆, SF₄, SOF₂, SO₂F₂, and WF₆.

 (35) A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas containing an inert gas, an oxygen-containing gas and at least two gases selected from the group consisting of SF₆,
20 F₂ and NF₃ excluding the combination of F₂ and NF₃ alone, and a decomposition step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

 (36) The method for producing a semiconductor device as described in (35) above, wherein the fluorocompound is at least one compound selected from the group consisting
25 of HF, SiF₄, SF₆, SF₄, SOF₂, SO₂F₂, and WF₆.

BRIEF DESCRIPTION OF DRAWING

30 Fig. 1 is a schematic view of etching equipment using the cleaning gas of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides "a cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, comprising an inert gas, SF_6 and one or both of F_2 and NF_3 " (the invention of the first cleaning gas), "a cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, comprising an inert gas, an oxygen-containing gas, SF_6 and one or both of F_2 and NF_3 " (the invention of the second cleaning gas), "a method for cleaning semiconductor production equipment, comprising use of the above-described cleaning gas" and "a method for producing a semiconductor device, comprising a cleaning step of using the above cleaning gas, and a decomposition step of decomposing a fluorocompound-containing gas discharged from the cleaning step".

The present invention is described in detail below.

The first cleaning gas for semiconductor production equipment of the present invention comprises an inert gas with any one of the three combinations,

- SF_6 and F_2 ,
- SF_6 and NF_3 , or
- SF_6 , F_2 and NF_3 .

(Hereinafter, the components other than the inert gas in the cleaning gas is referred to as "active gas".

The inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and N_2 . Among these, the inert gas is preferably at least one gas selected from the group consisting of He, Ar and N_2 , because the cleaning gas can exhibit high etching rate

and excellent cost performance.

The mixing ratio of the gas components in the cleaning gas of the present invention is not particularly limited, however, the ratio of the other gas components (NF₃, F₂ or NF₃ + F₂) is usually from 0.01 to 5, preferably from 0.1 to 1.5, and the inert gas is from 0.01 to 500, preferably from 0.1 to 300, more preferably from 0.1 to 30, in terms of the volume ratio assuming that SF₆ in the active gas components is 1. When used in production process of semiconductor production equipment or liquid crystal devices, it is preferable that the gas contains the active gas components in a large amount. However, if these gases are activated moreover in plasma on use, the equipment material in the plasma atmosphere may be damaged. On the other hand, if the amount added is too small, the effect is disadvantageously low. These gases may be mixed inside the semiconductor production equipment or in the pipeline leading to the semiconductor production equipment, or the gases may be previously mixed in a gas cylinder.

In the cleaning gas for semiconductor production equipment of the present invention, when F₂ and/or NF₃ gas capable of dissociating particularly at a low energy level and producing an active species is mixed, the effect brought out surpasses the effect by conventionally used cleaning gas or etching gas, such as CF₄ or C₂F₆. The synergistic effect by the mixing is presumed to occur because the active species produced at a low energy level acts on undissociated molecule in a chain-reaction manner and accelerates the dissociation.

The cleaning gas of the present invention may contain at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon,

perfluoroether and hydrofluoroether, in the mixed gas comprising an inert gas, SF_6 and one or both of F_2 and NF_3 . The perfluorocarbon and hydrofluorocarbon each is a compound having from 1 to 4 carbon atoms. Examples of the saturated perfluorocarbon compound include CF_4 , C_2F_6 and C_3F_8 , examples of the unsaturated perfluorocarbon compound include C_2F_4 , C_3F_6 and C_4F_6 , and examples of the hydrofluorocarbon include CHF_3 and $\text{C}_2\text{H}_2\text{F}_4$. The perfluoroether and hydrofluoroether each is a compound having from 2 to 4 carbon atoms. Examples of the perfluoroether include CF_3OCF_3 and $\text{CF}_3\text{OCF}_2\text{CF}_3$, and examples of the hydrofluoroether include $\text{CHF}_2\text{OCHF}_2$ and $\text{CHF}_2\text{OCH}_2\text{CF}_3$. The mixing ratio of the gas such as perfluorocarbon is from 0.01 to 1, preferably from 0.01 to 0.5, more preferably from 0.01 to 0.2, in terms of the volume ratio assuming that the mixed gas comprising SF_6 , F_2 , NF_3 and an inert gas is 1.

The second cleaning gas for semiconductor production equipment of the present invention comprises an inert gas, an oxygen-containing gas, and any one of the three combinations,

SF_6 and F_2 ,

SF_6 and NF_3 , or

SF_6 , F_2 and NF_3 .

(Hereinafter, the components, other than the inert gas and oxygen-containing gas in the cleaning gas, are referred to as "active gas".)

The oxygen-containing gas is at least one selected from the group consisting of O_2 , O_3 , N_2O , NO , NO_2 , CO and CO_2 . Particularly, it is preferable that the oxygen-containing gas is O_2 and/or N_2O , so that the etching rate of the cleaning gas is increased and thus the cost-performance is improved.

The inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and N₂. Among these, the inert gas is preferably at least one gas selected from the group consisting of He, Ar and N₂,
5 because the cleaning gas can exhibit high etching rate and excellent cost performance.

The mixing ratio of the gas components in the cleaning gas of the present invention comprising SF₆ with F₂ and/or NF₃, an oxygen-containing gas and an inert gas
10 is not particularly limited. However, the ratio is usually such

that F₂ and/or NF₃ is usually from 0.01 to 5, preferably from 0.1 to 1.5,

that the oxygen-containing gas is from 0.01 to 5,
15 preferably from 0.1 to 1.5, and

that the inert gas is from 0.01 to 500, preferably from 0.1 to 300, more preferably from 0.1 to 30, in terms of the volume ratio assuming that SF₆ is 1. When used for cleaning gas of manufacturing semiconductor
20 production equipment or liquid crystal devices, the oxygen-containing gas, SF₆, F₂ and NF₃ are active, which are preferably contained in a large amount. However, if these gases are activated moreover in plasma on use, the equipment material in the plasma atmosphere may be
25 damaged. On the other hand, if the amount added is too small, the effect is disadvantageously low. These gases may be mixed inside the semiconductor production equipment or in the pipeline leading to the semiconductor production equipment, or the gases may be previously
30 mixed in a gas cylinder.

The cleaning gas of the present invention may contain at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon,

perfluoroether and hydrofluoroether, in the mixed gas comprising an oxygen-containing gas, an inert gas, and SF₆ with F₂ and/or NF₃. The perfluorocarbon and hydrofluorocarbon each is a compound having from 1 to 4 carbon atoms. Examples of the saturated perfluorocarbon compound include CF₄, C₂F₆ and C₃F₈, examples of the unsaturated perfluorocarbon compound include C₂F₄, C₃F₆ and C₄F₆, and examples of the hydrofluorocarbon include CHF₃ and C₂H₂F₄. The perfluoroether and hydrofluoroether each is a compound having from 2 to 4 carbon atoms. Examples of the perfluoroether include CF₃OCF₃ and CF₃OCF₂CF₃, and examples of the hydrofluoroether include CHF₂OCHF₂ and CHF₂OCH₂CF₃. The mixing ratio of the gas such as perfluorocarbon is from 0.01 to 1, preferably from 0.01 to 0.5, more preferably from 0.01 to 0.2, in terms of the volume ratio assuming that the mixed gas comprising an oxygen-containing gas, an inert gas, and SF₆ with F₂ and/or NF₃ is 1.

The cleaning gas for semiconductor production equipment according to the present invention, comprising an oxygen-containing gas, an inert gas, and SF₆ with F₂ and/or NF₃, can exhibit effects superior to those provided by a conventional cleaning gas such as CF₄ and C₂F₆, by containing

- (1) F₂ and/or NF₃, gas which dissociates at a low energy level and produces an active species, and
- (2) oxygen atoms which are effective in producing and maintaining active species.

The effect involved by containing F₂ and/or NF₃ as a component in the mixed gas is presumed to occur because the active species produced at a low energy level acts on undissociated molecule in a chain-reaction manner and

accelerates the dissociation. The effect involved by containing oxygen as a component in the mixed gas is presumed to occur because the oxygen helps maintain activity of active species and prevents deactivation
5 caused by rebinding.

In the case of cleaning semiconductor production equipment using the cleaning gas of the present invention, the gas may be used under the plasma condition or under the plasmaless condition.

10 When the gas is used under the plasma condition, the excitation source is not particularly limited as long as plasma is excited from the cleaning gas of the present invention, but a microwave excitation source is preferred because good cleaning efficiency can be attained. Also,
15 the temperature and the pressure when the cleaning gas of the present invention is used are not particularly limited as long as plasma can be produced, but the temperature range is preferably from 50 to 500°C and the pressure range is preferably from 1 to 500 Pa.

20 In the case of plasmaless condition, the cleaning gas is introduced into a chamber, the inner pressure of the chamber is preferably set to 1 to 67 Pa and at least a part of or either one of the inside of chamber and the cleaning gas is heated at 200 to 500°C to generate free
25 fluorine having reactivity from the cleaning gas. Then, deposits are etched and removed from the chamber and from other regions where deposits are accumulated, and thereby the semiconductor production equipment can be cleaned.

Fig. 1 is a view showing one example of the etching
30 equipment using the cleaning gas of the present invention. The cleaning gas is introduced into a chamber 1 set at a constant temperature from a cleaning gas inlet 6 and at

this time, the gas is excited by a microwave plasma excitation source 4 and produces plasma. The gas obtained after the etching of a silicon wafer 2 on sample stage 3 is discharged by a dry pump 5 and rendered harmless using a decomposing agent according to the kind of the gases contained therein. Furthermore, the deposits accumulated after the etching are efficiently removed by repeating the same operation as the etching, and thereby the chamber can be efficiently cleaned.

10 The method for producing a semiconductor device of the present invention is described below.

As described above, according to the present invention, the cleaning of semiconductor production equipment can be efficiently performed. However, the gas discharged from the cleaning step using the cleaning gas of the present invention contains fluorocompounds such as HF, SiF₄, SF₄, SOF₂, SO₂F₂ and WF₆, in addition to SF₆, F₂ and NF₃ used as the cleaning gas. If these compounds including SF₆, F₂ and NF₃ are discharged intact into atmosphere, they greatly affect the global warming or generate an acid gas by decomposition, therefore, each compound must be completely rendered harmless. In the method for producing a semiconductor device, the present invention provides a production method of a semiconductor device, comprising a cleaning step of cleaning semiconductor production equipment and a step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

The step of cleaning semiconductor production equipment can be efficiently performed by using the method described above. The method for use in the step of decomposing the fluorocompound-containing gas discharged from the cleaning step is not particularly

limited and the decomposing agent can be appropriately selected according to the kind of the compound contained in the exhaust gas. However, hydrogen fluoride, SO_x and the like are preferably fixed as a fluoride or a sulfate of metal, and carbon is preferably discharged after completely decomposing it into carbon dioxide.

BEST MODE FOR CARRYING OUT THE INVENTION

The present invention is described in greater detail below by referring to the Examples and Comparative Examples, however, the present invention is not limited to these Examples.

Examples 1 to 3

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 1 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a silicon wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicon wafer after etching and the results are shown in Table 1.

[Table 1]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF_6	F_2	He	
1	1	1	200	200
2	1	0.5	170	180
3	1	1.5	250	190

Examples 4 to 6

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 2 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a silicon wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicon wafer after the etching and the results are shown in Table 2.

[Table 2]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF ₆	NF ₃	He	
4	1	1	200	200
5	1	0.5	170	180
6	1	1.5	250	190

15

Comparative Examples 1 to 5

The etching rate of each cleaning gas was determined in the same manner as in Examples 1 to 6 except that the cleaning gas was changed to a gas having the composition shown in Table 3.

20

[Table 3]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)		Etching Rate (nm/min)
	Gas Used	Mixing Ratio	
1	NF ₃ /He	1/100	190
2	SF ₆ /He	1/100	70
3	F ₂ /He	1/100	170
4	CF ₄ /He	1/100	17
5	C ₂ F ₆ /He	1/100	6

Among the cleaning gases mixed with He shown in Table 3, the etching rate was highest in the case of using NF₃.

Comparative Examples 6 to 8

The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gases were changed to the gases each having the composition shown in Table 4.

[Table 4]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	NF ₃	F ₂	He	
6	1	1	200	175
7	1	0.5	170	170
8	1	1.5	250	170

All of the etching rate of the mixed gases shown in

Comparative Examples 6 to 8 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 6.

5 Comparative Examples 9 to 11

The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gases were changed to the gases each having the composition shown in Table 5.

10

[Table 5]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	CF ₄	F ₂	He	
9	1	1	200	140
10	1	0.5	170	120
11	1	1.5	250	155

15 All of the etching rate of the mixed gases shown in Comparative Examples 9 to 11 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 6.

Comparative Examples 12 to 14

20 The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gases were changed to the gases each having the composition shown in Table 6.

[Table 6]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	C ₂ F ₆	F ₂	He	
12	1	1	200	50
13	1	0.5	170	30
14	1	1.5	250	100

All of the etching rate of the mixed gases shown in Comparative Examples 12 to 14 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 6.

Comparative Example 15

The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gas was changed to a gas having the composition shown in Table 7.

[Table 7]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)		Etching Rate (nm/min)
	Gas Used	Mixing Ratio	
15	NF ₃ /He	1/10	1,900

It is seen that when the concentration of NF₃ was increased to ten times that of Comparative Example 1, the etching rate also became ten times higher.

Example 7

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 1 to 3 except that the cleaning gas was changed

to a gas having the composition shown in Table 8.

[Table 8]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF ₆	F ₂	He	
7	1	1	20	2,200

The etching rate of the cleaning gas of the present invention shown in Example 7 was more excellent than the rate of NF₃ shown in Comparative Example 15.

Example 8

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 4 to 6 except that the cleaning gas was changed to a gas having the composition shown in Table 9.

[Table 9]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF ₆	NF ₃	He	
8	1	1	20	2,200

The etching rate of the cleaning gas of the present invention shown in Example 8 was more excellent than the rate of NF₃ shown in Comparative Example 15.

Examples 9 to 11

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 10 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a

silicon wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicon wafer after the etching and the results are shown in Table 10.

5

[Table 10]

Example	Gas Used and Mixing Ratio (Volume Ratio)				Etching Rate (nm/min)
	SF ₆	F ₂	O ₂	He	
9	1	1	0.5	200	300
10	1	0.5	0.5	170	260
11	1	1.5	0.5	250	290

Comparative Example 16 to 18

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 9 to 11 except that the cleaning gas was changed to a gas having the composition shown in Table 11.

[Table 11]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)				Etching Rate (nm/min)
	NF ₃	F ₂	O ₂	He	
16	1	1	0.5	200	170
17	1	0.5	0.5	170	160
18	1	1.5	0.5	250	160

15

All of the etching rate of the mixed gases shown in Comparative Examples 16 to 18 were lower than the rate of the cleaning gases of the present invention shown in Examples 9 to 11.

Example 12

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 9 to 11 except that the cleaning gas was changed to a gas having the composition shown in Table 12.

[Table 12]

Example	Gas Used and Mixing Ratio (Volume Ratio)				Etching Rate (nm/min)
	SF ₆	F ₂	O ₂	He	
12	1	1	0.5	20	3,000

The etching rate of the cleaning gas of the present invention shown in Example 12 was more excellent than the rate of NF₃ shown in Comparative Example 15.

Example 13

In place of a silicon wafer, a quartz piece having accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning. The cleaning gas used in Example 1 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus adjusted to an inner pressure of 300 Pa, and the quartz piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

Example 14

In place of a silicon wafer, a quartz piece having accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning.

The cleaning gas used in Example 4 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus adjusted to an inner pressure of 300 Pa, and the quartz
5 piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

Example 15

In place of a silicon wafer, a quartz piece having
10 accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning. The cleaning gas used in Example 9 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus
15 adjusted to an inner pressure of 300 Pa, and the quartz piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

INDUSTRIAL APPLICABILITY

20 The cleaning gas for semiconductor production equipment of the present invention is high in the etching rate, therefore, ensures efficient cleaning and excellent cost performance. According to the method for cleaning semiconductor production equipment of the present
25 invention, unnecessary deposits in the film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid crystal element accumulated at the film-formation or etching of silicon, silicon nitride, silicon oxide, tungsten or the like can be
30 efficiently removed. Furthermore, by using the method comprising a cleaning step of using the cleaning gas of the present invention and a step of decomposing and thereby rendering harmless the fluorocompound-containing

exhaust gas discharged from the cleaning step, a semiconductor device can be efficiently produced.

CLAIMS

1. A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits
5 in the equipment, comprising an inert gas and at least two gases selected from the group consisting of SF₆, F₂, and NF₃ excluding the combination of F₂ and NF₃ alone.
2. The cleaning gas for semiconductor production
10 equipment as described in claim 1, comprising SF₆, F₂, and an inert gas.
3. The cleaning gas for semiconductor production equipment as described in claim 1, comprising SF₆, NF₃,
15 and an inert gas.
4. The cleaning gas for semiconductor production equipment as described in claim 1, comprising SF₆, F₂, NF₃,
and an inert gas.
20
5. The cleaning gas for semiconductor production equipment as described in any one of claims 1 to 4, wherein the inert gas is at least one selected from the group consisting of He, Ne, Ar, Xe, Kr and N₂.
25
6. The cleaning gas for semiconductor production equipment as described in claim 5, wherein the inert gas is at least one selected from the group consisting of He, Ar, and N₂.
30
7. The cleaning gas for semiconductor production equipment as described in claim 1, wherein F₂ and/or NF₃ is from 0.01 to 5 and the inert gas is from 0.01 to 500

in terms of the volume ratio assuming that SF_6 is 1.

8. The cleaning gas for semiconductor production equipment as described in claim 7, wherein F_2 and/or NF_3 is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that SF_6 is 1.

9. The cleaning gas for semiconductor production equipment as described in claim 1, which contains at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.

10. The cleaning gas for semiconductor production equipment as described in claim 9, wherein the perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and hydrofluoroether each has from 2 to 4 carbon atoms.

11. A cleaning gas for semiconductor production equipment, which is a gas for removing deposits in the equipment, comprising an oxygen-containing gas, an inert gas and at least two gases selected from the group consisting of SF_6 , F_2 , and NF_3 excluding the combination of F_2 and NF_3 alone.

12. The cleaning gas for semiconductor production equipment as described in claim 11, comprising an oxygen-containing gas, an inert gas, SF_6 , and F_2 .

13. The cleaning gas for semiconductor production equipment as described in claim 11, comprising an oxygen-containing gas, an inert gas, SF_6 , and NF_3 .

14. The cleaning gas for semiconductor production equipment as described in claim 11, comprising an oxygen-containing gas, an inert gas, SF_6 , F_2 and NF_3 .

5

15. The cleaning gas for semiconductor production equipment as described in any one of claims 11 to 14, wherein the oxygen-containing gas is at least one selected from the group consisting of O_2 , O_3 , N_2O , NO , NO_2 ,
10 CO and CO_2 .

16. The cleaning gas for semiconductor production equipment as described in claim 15, wherein the oxygen-containing gas is O_2 and/or N_2O .

15

17. The cleaning gas for semiconductor production equipment as described in any one of claims 11 to 14, wherein the inert gas is at least one selected from the group consisting of He , Ne , Ar , Xe , Kr and N_2 .

20

18. The cleaning gas for semiconductor production equipment as described in claim 17, wherein the inert gas is at least one selected from the group consisting of He , Ar , and N_2 .

25

19. The cleaning gas for semiconductor production equipment as described in claim 11, wherein F_2 and/or NF_3 is from 0.01 to 5, the oxygen-containing gas is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms of
30 the volume ratio assuming that SF_6 is 1.

20. The cleaning gas for semiconductor production equipment as described in claim 19, wherein F_2 and/or NF_3

is from 0.1 to 1.5, the oxygen-containing gas is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that SF_6 is 1.

- 5 21. The cleaning gas for semiconductor production equipment as described in claim 11, which contains at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.
- 10 22. The cleaning gas for semiconductor production equipment as described in claim 21, wherein the perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and
- 15 hydrofluoroether each has from 2 to 4 carbon atoms.
23. A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of claims 1 to 10.
- 20 24. The method for cleaning semiconductor production equipment as described in claim 23, wherein the cleaning gas described in any one of claims 1 to 10 is excited to produce plasma and the deposits in the semiconductor
- 25 production equipment are removed in the plasma.
25. The method for cleaning semiconductor production equipment as described in claim 24, wherein the excitation source for the plasma is a microwave.
- 30 26. The method for cleaning semiconductor production equipment as described in any one of claims 23 to 25, wherein the cleaning gas described in any one of claims 1

to 10 is used at a temperature range of 50 to 500°C.

27. The method for cleaning semiconductor production equipment as described in claim 23, wherein the cleaning
5 gas described in any one of claims 1 to 10 is used at a temperature range of 200 to 500°C in a plasmaless system.

28. A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described
10 in any one of claims 11 to 22.

29. The method for cleaning semiconductor production equipment as described in claim 28, wherein the cleaning gas described in any one of claims 11 to 22 is excited to
15 produce plasma and the deposits in the semiconductor production equipment are removed in the plasma.

30. The method for cleaning semiconductor production equipment as described in claim 29, wherein the
20 excitation source for the plasma is a microwave

31 The method for cleaning semiconductor production equipment as described in any one of claims 28 to 30, wherein the cleaning gas described in any one of claims
25 11 to 22 is used at a temperature range of 50 to 500°C.

32. The method for cleaning semiconductor production equipment as described in claim 28, wherein the cleaning gas described in any one of claims 11 to 22 is used at a
30 temperature range of 200 to 500°C in a plasmaless system.

33. A method for producing a semiconductor device,

comprising a cleaning step of using a cleaning gas containing an inert gas and at least two gases selected from the group consisting of SF_6 , F_2 and NF_3 excluding the combination of F_2 and NF_3 alone, and a decomposition step
5 of decomposing a fluorocompound-containing gas discharged from the cleaning step.

34. The method for producing a semiconductor device as described in claim 33, wherein the fluorocompound is at
10 least one compound selected from the group consisting of HF , SiF_4 , SF_6 , SF_4 , SOF_2 , SO_2F_2 , and WF_6 .

35. A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas
15 containing an inert gas, an oxygen-containing gas and at least two gases selected from the group consisting of SF_6 , NF_3 and F_2 excluding the combination of F_2 and NF_3 alone, and a decomposition step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

20 36. The method for producing a semiconductor device as described in claim 35, wherein the fluorocompound is at least one compound selected from the group consisting of HF , SiF_4 , SF_6 , SF_4 , SOF_2 , SO_2F_2 , and WF_6 .

25

Fig. 1

